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AN ANALYSIS OF PIPELINE PERFORMANCE IN ALBERTA

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1 INTRODUCTION

Over 204 000 kilometres of pipeline beneath Alberta, including some 82 000 kilometres of gas distribution lines, transport the production of oil and gas resources. Worldwide, pipelines represent a major transportation network moving many types of products and services through lines constructed of steel, cast iron, concrete, asbestos cement, plastics, and reinforced glass fibre. Operating conditions vary for the transportation of different products and thus determine the design of pipelines; nevertheless, pipelines operate with a high degree of safety and economy and exist compatibly with the surrounding environment.

The service life of pipelines can extend at least forty years. Despite proper operating and maintenance practices during service life, a pipeline may fail from any number of causes. A failure, which in general terms includes any leak or break however small or large, is usually a stable event and its extent is limited to a localized area of the pipe. In most cases, the consequences are small and little associated hazard exists.

Often pipelines operating under similar conditions have the same kind of recurring leaks. The causes of pipeline leaks can be related to the type of line service and trends in pipeline operations can be established from a comparison of similar pipeline systems. The widely accepted engineering technique of using evaluation and analysis of failures to identify necessary changes in design, construction, and operation of structures can be readily applied to pipelines.

Pipeline leaks in Alberta without limitation of cause, magnitude, or consequence are reported to the Board by the operators. Data is collected as it relates to the transmission of crude oil and oil products, sweet natural gas, sour natural gas[1], multiphase fluids[2], salt water, and fresh water. The information compiled on each leak includes a description by one of eighteen cause categories (Table 1), date of occurrence, geographic location, and some general pipe specifications and operating conditions.

An estimate of product volume spilled after a leak is recorded but the use of this data is limited in pipeline performance evaluation. All leaks have occurred by the time the product is released from a pipeline. In an engineering assessment, spill volumes do not influence leak initiation or affect its propagation in the pipe material.

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[1] Contains hydrogen sulphide gas in quantities of 10 mol/kmol or greater.

[2] Well effluent, may contain oil, gas, and water, or any combination thereof.

TABLE 1 PIPELINE LEAK/BREAK CAUSE CATEGORIES

Corrosion:	1.	Internal Corrosion (CI)
	2.	External Corrosion (CX)
	3.	Corrosion at girth or fillet weld (CW)
External Forces:	4.	Construction Damage (CD) - includes leaks resulting from damage during original pipeline construction or improper construction practices.
	5.	Damage by Others (DO) - third-party damage caused by external interference such as excavation equipment.
	6.	Earth Movement (EM)
Joint:	7.	Mechanical Joints (JF) - mechanical-type joints (ie screwed couplings, interference fit joints).
	8.	Miscellaneous Joints (MJ) - includes fusion or welded joints of plastic, reinforced glass fibre, and aluminum pipe.
Weld:	9.	Girth Weld (GW)
	10.	Other Welds (WF)
	11.	Seam Rupture (SR) - seam weld breaks.
Equipment:	12.	Installation (IF) - leaks at a compressor station, pumping, meter station, etc.
	13.	Valve/Fitting Failure (VF)
Others:	14.	Pipe (PF) - breaks in the pipe body.
	15.	Overpressure (OP)
	16.	Operator Error (OE)
	17.	Miscellaneous (MS)
	18.	Unknown (UN)

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The frequency of leaks such as corrosion may be influenced by the age of the operating pipeline. The Board is presently investigating the influence of pipe age on leak rates and anticipates that the analysis results will be available in the near future.

This report will outline the Board's Pipeline Leak Data Base and discuss the overall performance of pipelines used in the oil and gas industry.

2 PIPELINE LEAK DATA BASE

Since 1975, pipeline leaks have been recorded on a computer-assisted record system within the Board. A standard set of reporting requirements has been followed without change during this period. The reporting format has also remained essentially unchanged with minor alterations only being made in order to refine the system, clarify data received, and eliminate any inconsistencies in reporting. As a result, a consistent and standard set of data has been collected since 1975, covering some 3900 leaks and breaks.

Statistics were compiled following two intensive reviews of the data base conducted in 1978 and 1982. Each review examined all original leak reports and checked for completeness, accuracy, and computer editing.

The following statistics represent all pipeline leaks without limitation of cause, magnitude, or consequence associated with the event. Included are all pipelines related to the oil and gas industry and within the Board's jurisdiction. No volume limitations are placed on product release for the leak to be accounted in the statistics. The only leaks excluded are those of low pressure gas distribution lines operating at pressures less than 700 kilopascals.

3 PIPELINE PERFORMANCE IN ALBERTA

3.1 Relative Performance of Different Pipeline Types

Figure 1 represents annual pipeline leaks and breaks in Alberta covering the period 1975-1982. Leaks are shown by five pipeline categories: oil, water, multiphase fluids, sweet gas, and sour gas. In 1982, the total number of leaks in the province increased, and continued a trend shown for the past several years. During the 8-year period, pipeline leaks increased by 31 per cent; the length of operating pipelines increased over 100 per cent from about 58 000 kilometres to 122 000 kilometres. Thus since 1975, total pipeline length has grown at a faster rate than the incidence of leaks resulting in an overall decrease in pipeline leak rate. In 1975, an average of 8 leaks occurred per 1000 kilometres of operating pipelines; in 1982, 5 leaks occurred per 1000 operating kilometres.

Leaks of each type of pipeline fluctuate from year to year. However, the distribution of all leaks by line type has remained relatively constant. The majority have continued to occur on multiphase and water lines; each represent about one-third of the total. Oil and gas lines represent the remaining one-third of leaks with sour gas lines accounting for about 1 in 30 leaks in the province.

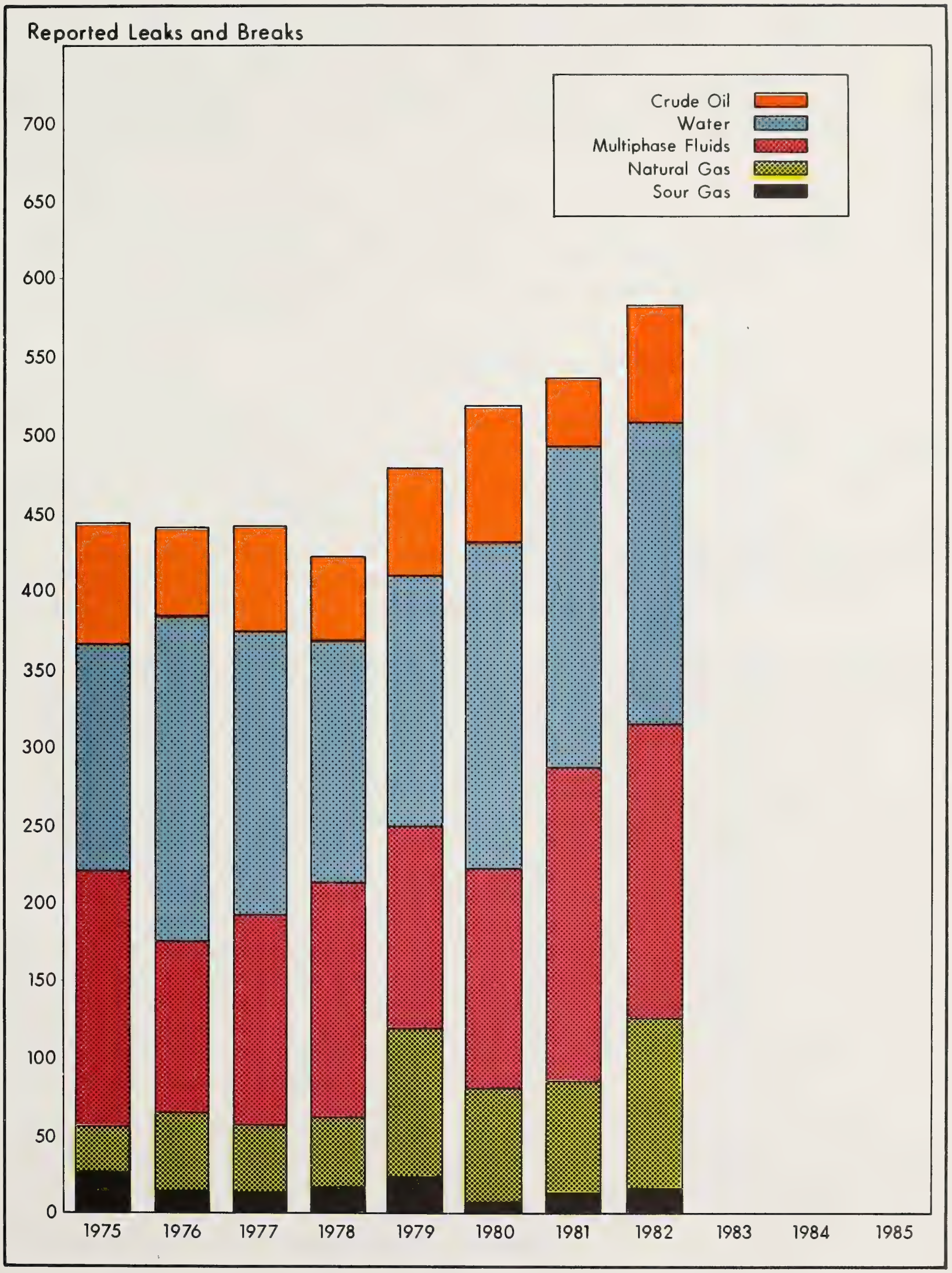

FIGURE 1 ANNUAL PIPELINE LEAKS AND BREAKS

In contrast, gas lines account for the largest portion of operating pipeline length in the province; water lines represent the smallest portion of total length. Over one-half of province-wide pipelines operate in gas service, and almost one-quarter of the total length operate in oil service. Multiphase and water lines represent the remaining one-quarter of pipelines in operation; in fact, one-tenth of all pipelines operate in water service.

Thus, each year most leaks occur on water lines which operate with the least portion of pipeline length. In 1982, water lines continued to leak with greatest frequency, some 16 per 1000 operating kilometres (Figure 2). The leak rate of gas lines was lowest at a rate of 2 per 1000 operating kilometres.

3.2 Major Causes of Province-wide Leaks and Breaks

Historical data shows corrosion to be the leading cause of leaks. In 1982, over one-half of all pipeline leaks were due to corrosion of which corrosion to the interior pipe wall occurred twice as often as that of the exterior wall (Figure 3). A large portion of the corrosion is distributed on two types of lines: two-thirds of all internal corrosion occurs on water lines and over one-half of all external corrosion occurs on multiphase lines. These leaks are characteristic of each pipeline service and will be further discussed in individual sections.

As with most corrosion, the line leaks are due to isolated pitting or general wall thinning in a localized area. A leak mode will generally occur from a small opening in a pipe, such as a pinhole or a crack, whose dimensions remain stable during the release of product (Figure 4).

Pipeline damage caused by external interference such as excavation equipment (third-party damage) occurs frequently and in 1982 accounted for 12 per cent of all leaks and breaks. Pipeline damage due to external interference can occur on any type of line, independent of the product transported. Damage records indicate that the greater the depth of a buried pipeline, the less likelihood of damage. Third-party damage occurs on multiphase lines with greatest frequency, some 1.1 breaks per 1000 operating kilometres per year. By comparison, water line breaks due to third-party damage occur least frequently, at some 0.4 per 1000 operating kilometres per year. The low rate of water lines may be due to a deeper burial than either oil or gas lines which prevents water freezing during the winter.

Third-party damage is particularly significant because the break mode initiated by pipeline contact is usually a rupture (Figure 4); a rupture is a major pipe opening caused by the instantaneous tearing or fracturing of the pipe material. A rupture immediately impairs the operation of a pipeline and can cause significant damage.

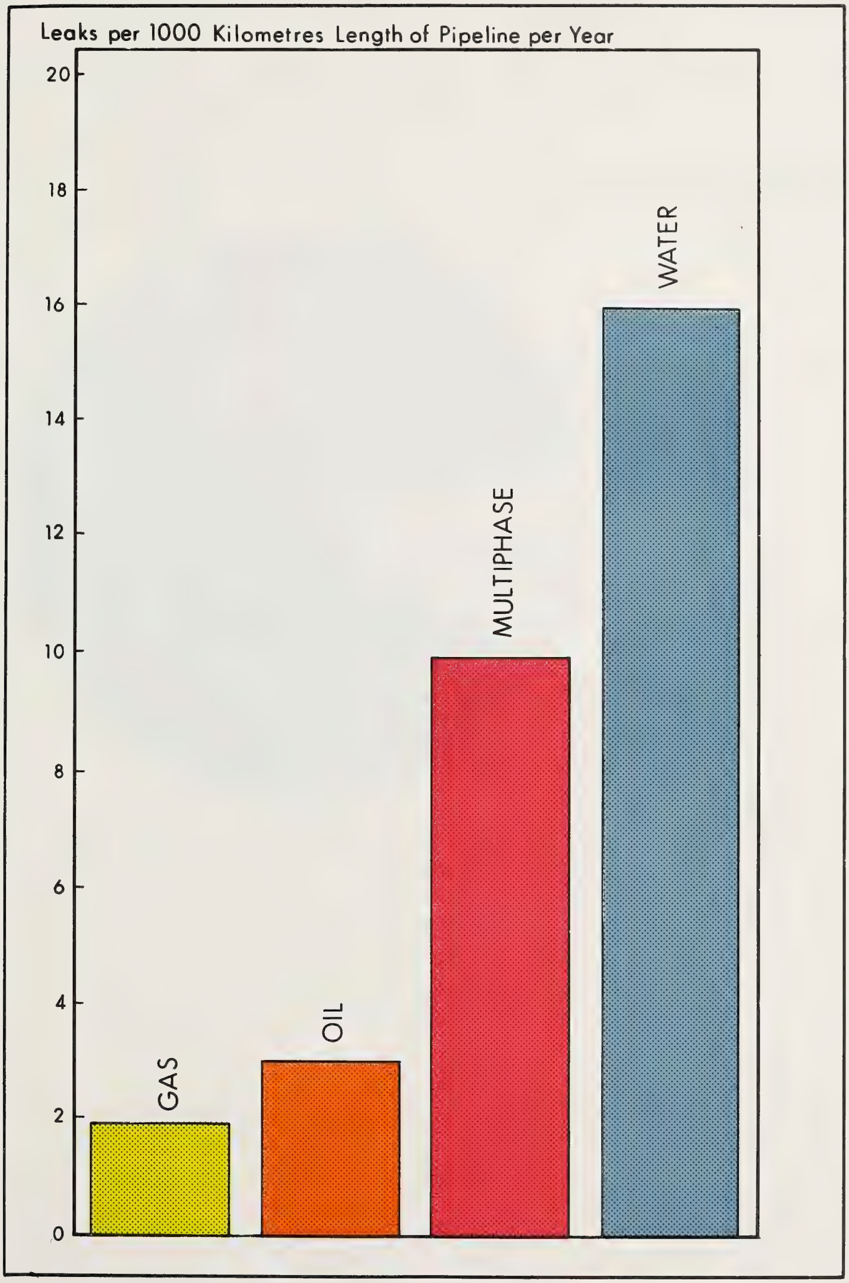

FIGURE 2 1982 FREQUENCY OF PIPELINE LEAKS AND BREAKS

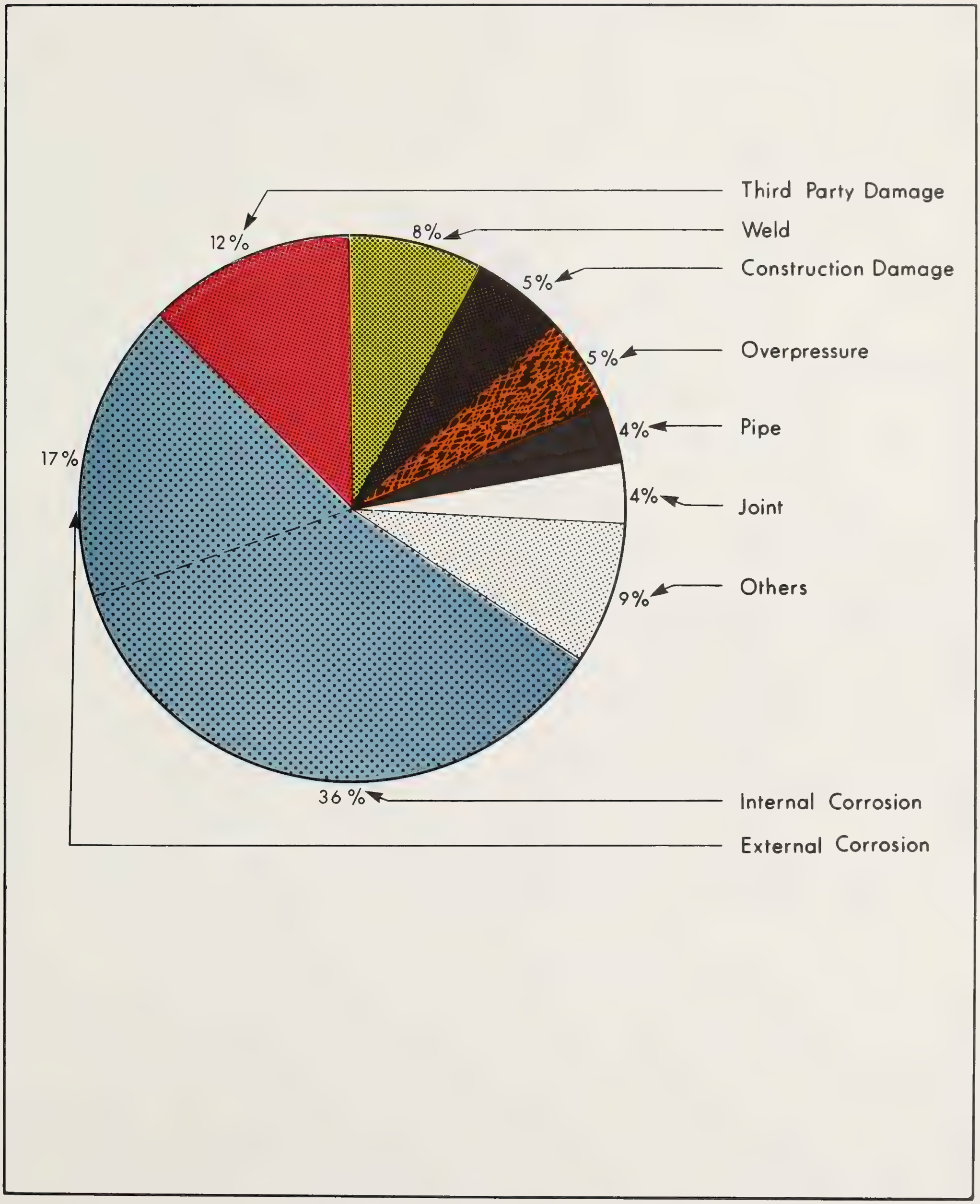

FIGURE 3 DISTRIBUTION OF LEAKS AND BREAKS BY CAUSE

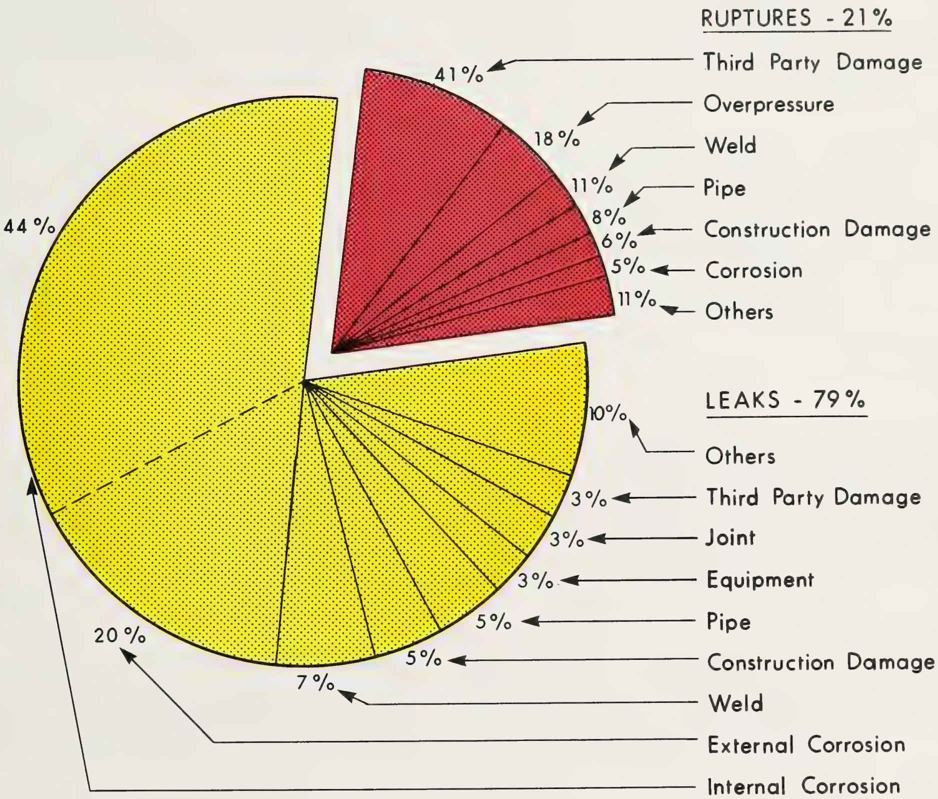

FIGURE 4 1975-1982 CAUSE OF LEAKS Vs. CAUSE OF RUPTURES.

In 1982, about one-quarter of the leaks were caused by defects in welds, joints, or pipe body; damage during installation (construction damage); and overpressure (Figure 3). The incidence of these leaks is low and distributed equally on each line type and generally independent of the product carried. There is little variation in the quality standards of pipe material and jointing methods used for each pipeline service in the oil and gas industry. Construction damage is usually due to pipe transportation and handling, and poor construction practices. Construction damage to water lines is greater than other lines due to the brittle nature and low impact resistance of some internal coatings.

Overpressure breaks are more likely to occur on liquid lines than gas lines. Overpressure occurs on multiphase lines with greatest frequency, some 1.1 breaks per 1000 operating kilometres per year. By comparison, overpressure of gas lines is virtually non-existent. The variation in break rates may be attributed to the differing characteristics of products carried in liquid and gas lines; natural gas is highly compressible whereas liquids are not. As such, gas tends to be much more forgiving to pressure variations than fluids.

3.3 Performance of Water Pipelines

Water line leaks represent one-third of the annual province-wide total. Internal corrosion causes over one-half of water line leaks (Figure 5), and in 1982, occurred at a rate of 10 per 1000 operating kilometres. By comparison, the frequency of internal corrosion leaks on multiphase lines was 3 per 1000 operating kilometres, on oil lines was 1 per 1000 operating kilometres, and on gas lines was less than 0.1 per 1000 operating kilometres.

The aggressive nature of produced water has led to widespread use of internal coatings on pipelines for water service. Conversely, coating protection of the interior pipe wall of oil or gas lines is virtually non-existent. The use of internally coated pipe has caused some construction and operational faults leading to water line leaks.

Girth weld leaks of water lines occur frequently. On average, 0.6 leaks occur per 1000 operating kilometres per year, some 6 times the frequency of oil and gas lines. Coatings, and in particular cement linings, alter the cross-sectional profile of girth welds and impair effective field welding practices. An excessive amount of stress may be present at welded joints causing cracks to propagate in the weld and cause leaks.

Construction damage frequently causes water line leaks during service life. On average, 1.1 leaks occur per 1000 operating kilometres per year, some 5 times the frequency of oil or gas lines. Careful handling of cement-lined pipe during transportation and construction is required in order to avoid complete or partial coating disbondment which exposes bare pipe to a corrosive environment. Since 1980, a continued reduction has been evident in the frequency of leaks due to construction damage. This coincides with an increase in the use of elastic linings such as epoxy bondings and plastics.

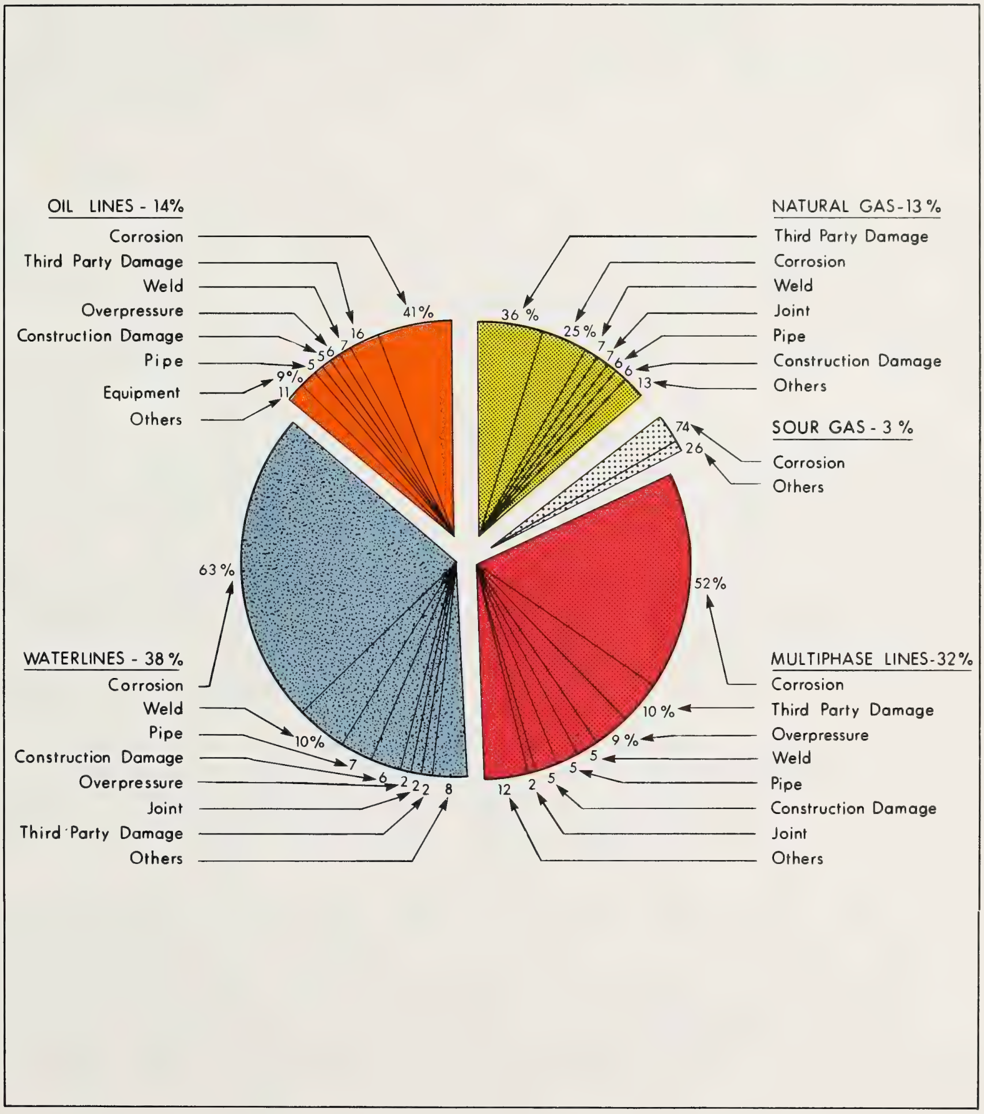

FIGURE 5 1975 to 1982 PIPELINE LEAKS AND BREAKS
(The Main Causes by Type of Pipeline)

The trends in water line leaks from 1975-1982 are shown in Figure 6. The incidence of water line leaks appears to cycle as pipe manufacturers and operators investigate different materials for water service. The design of water lines must address the compatibility of internal coatings with joint design and construction methods in order to reduce leak rates. As reservoir production declines, water production will generally increase and the throughput on water lines will also increase, aggravating the present problems.

3.4 Performance of Multiphase Pipelines

Similar to water lines, multiphase line leaks represent one-third of the annual province-wide total of which over one-half of the leaks are due to corrosion (Figure 5). However, corrosion initiated in the external pipe wall causes more leaks than internal corrosion. On average, 3 leaks occur per 1000 operating kilometres per year, some 3 times the frequency of water lines, 6 times the frequency of oil lines, and 10 times the frequency of gas lines.

Many operating multiphase lines were constructed of bare steel pipe and have been in service many years. Cathodic protection has only recently been applied to the older lines. Often, external corrosion is due to the natural degradation of bare steel pipe in service for over some 20 years.

Third-party damage frequently causes multiphase line breaks. On average, 1.1 breaks occur per 1000 operating kilometres per year. The high susceptibility to external interference may be attributed to the shallow depths of older lines and poor records of the existence and location of multiphase lines.

Overpressure of multiphase lines often occurs during pigging and hot oiling operations. These small diameter pipelines are easily overpressured when wax builds up ahead of a cleaning pig, a line plug forms, and the pig becomes stuck. Little liquid compressibility is inherent and a small pump can very quickly overpressure the line.

Material leaks occur with low incidence on multiphase lines. Leaks of girth welds, seam welds and the pipe body are of little significance due in part to operating conditions. Defects in the small diameter pipe seldom propagate and cause leaks because low operating pressures do not induce significant pipe stress levels. This is supported by over 40 years of operation of many multiphase lines which were constructed prior to current pipe manufacture and welding standards.

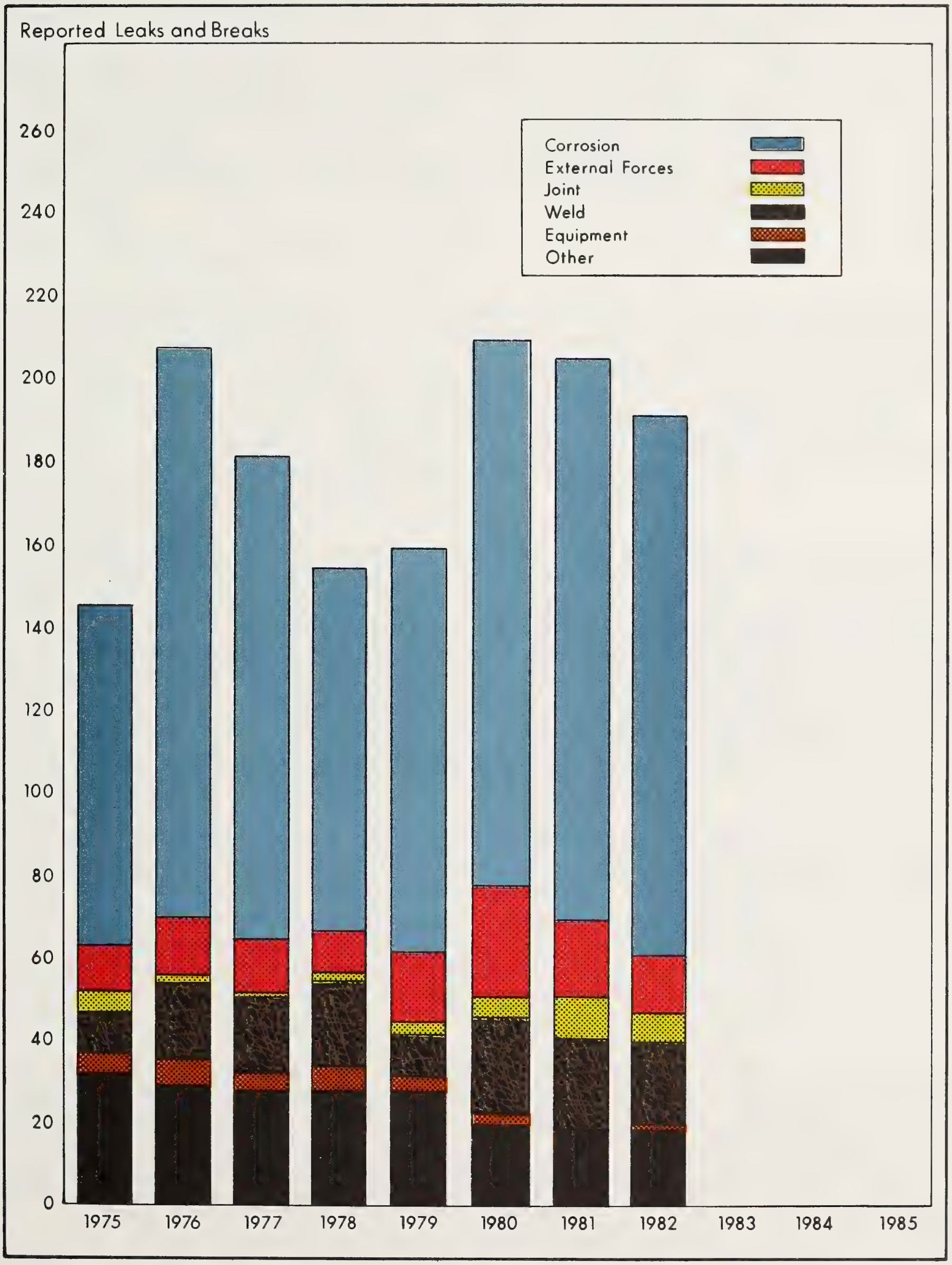

FIGURE 6 ANNUAL PIPELINE LEAKS AND BREAKS. Water Lines

The distribution of multiphase line leaks from 1975-1982 is shown in Figure 7. The large fluctuation in leaks over the 8-year period is mainly due to corrosion, third-party damage, and operator dependent leaks. Some degree of variation can be expected of leaks due to third-party damage since external interference is not always predictable. Present standards ensure external protection and accurate locations of new pipelines in order to reduce corrosion and third-party damage. Overpressure remains a common leak cause influenced by operating practices.

3.5 Performance of Oil Pipelines

The materials transported in the category of oil lines include crude oil, condensate, synthetic crude oil, and high vapour pressure[3] products. In general, oil pipelines transmit production from batteries and pumping stations to other facilities. Leaks of crude oil pipelines represent about 90 per cent of all oil line leaks and condensate and high vapour pressure pipelines each represent 5 per cent of the total. Leaks of high vapour pressure pipelines represent the fraction of less than 1 in 160 total leaks of all pipelines.

Corrosion is the leading cause of oil line leaks accounting for almost one-half of the total (Figure 5). However, the frequency of corrosion is lower than other liquid lines. On oil lines, 1 internal corrosion leak occurs per 1000 operating kilometres per year. By comparison, internal corrosion leaks occur some 3 times more frequently on multiphase lines and 10 times more frequently on water lines. External corrosion leaks of oil lines occur at an average rate of 0.5 per 1000 operating kilometres per year. By comparison, external corrosion leaks occur some 3 times more frequently on water lines and 6 times more frequently on multiphase lines.

Of particular significance on oil lines are valve and fitting leaks and equipment leaks at installations. The frequency of these leaks is high, accounting for about 11 per cent of the total. On average, 0.3 leaks occur per 1000 operating kilometres per year, some 3 times that of gas lines. Most leaks occur from gaskets, seals, and connections such as screwed fittings and nipples. During the past 8 years, there has been no record of a structural break in the body of valves, fittings, or equipment.

The distribution of oil line leaks for the period 1975-1982 is shown in Figure 8. Although each category has fluctuated, the leak rates are low. Leaks caused by corrosion, material defects, and third-party damage occur at or less than the rate of other pipelines. Equipment leaks are of greater significance on oil lines yet have reduced in occurrence since 1975.

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[3] High vapour pressure pipelines transmit ethane, propane, butane, or any combination with crude oil or condensate which produces a vapour pressure in excess of 240 kPa at 38°C.

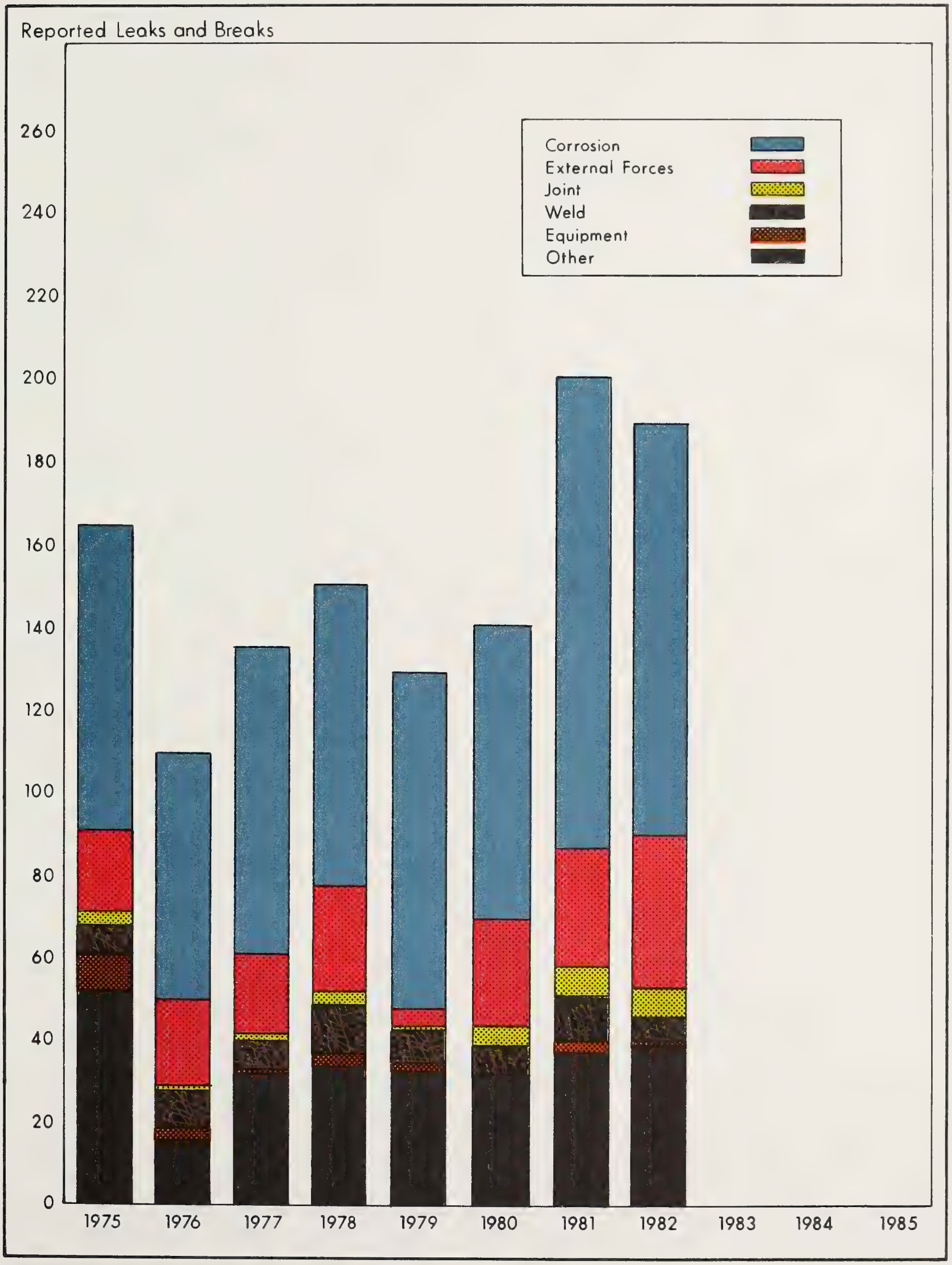

FIGURE 7 ANNUAL PIPELINE LEAKS AND BREAKS. Multiphase Fluids

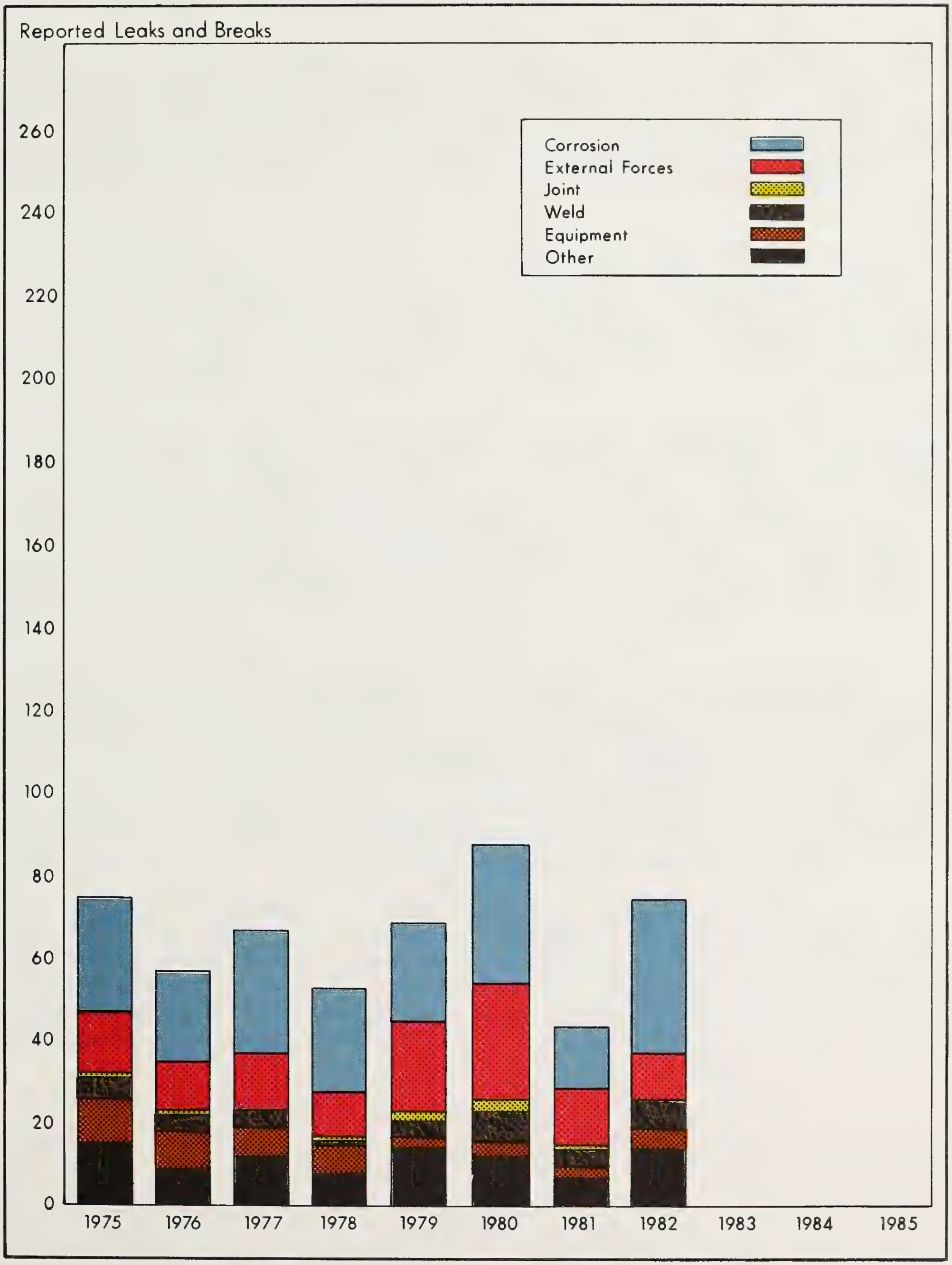

FIGURE 8 ANNUAL PIPELINE LEAKS AND BREAKS. Crude Oil (Includes Propane, Condensates and Synthetic Crude)

3.6 Performance of Natural Gas Pipelines

Gas lines have the lowest leak rate; in 1982, 2 leaks occurred per 1000 operating kilometres (Figure 2). The major causes of leaks are distributed differently on sweet natural gas lines. Figure 5 shows third-party damage causing about one-third of the breaks. However, the frequency is low and on average, 0.5 breaks occur per 1000 operating kilometres per year, or about one-half the frequency of multiphase lines.

The leak distribution essentially shows a low incidence of corrosion. On average, 0.1 internal corrosion leaks occur per 1000 operating kilometres per year, and 0.3 external corrosion leaks occur per 1000 operating kilometres per year. By comparison, on water lines, internal corrosion occurs at 100 times the frequency and external corrosion occurs at 30 times the frequency.

Defects in welds, joints, and the pipe body are also shown as main causes of gas line leaks (Figure 5). Girth welds appear as a more significant cause of leaks. However, the leak rate is low and, on average, 0.1 leaks occur per 1000 operating kilometres per year, or about one-sixth the frequency of water lines. Assuming 12-metre pipe joints, 1 girth weld leaks in over 820 000 welded joints of gas lines each year. The leak rate of girth welds indicates few design or field welding inadequacies on gas lines.

Operation caused leaks, significant on liquid lines, are of little concern on gas lines. Overpressure is virtually non-existent and there is no record of a gas line leak initiated by human error during the 8-year statistical history. It is suggested that operation induced leaks are less likely to occur on gas lines as most pressure surges are absorbed by gas compressibility. Any human error has to be excessive to cause a leak. A large compressor would be required to produce pressures creating abnormally high stress levels in any size of line pipe.

The distribution of sweet gas line leaks from 1975-1982 is shown in Figure 9. The number of leaks caused by corrosion, girth welds, and third-party damage has increased over the 8 year period. However, little effect has occurred on leak rates because gas lines represent the single greatest length of pipeline in service in Alberta numbering over 69 000 operating kilometres at present.

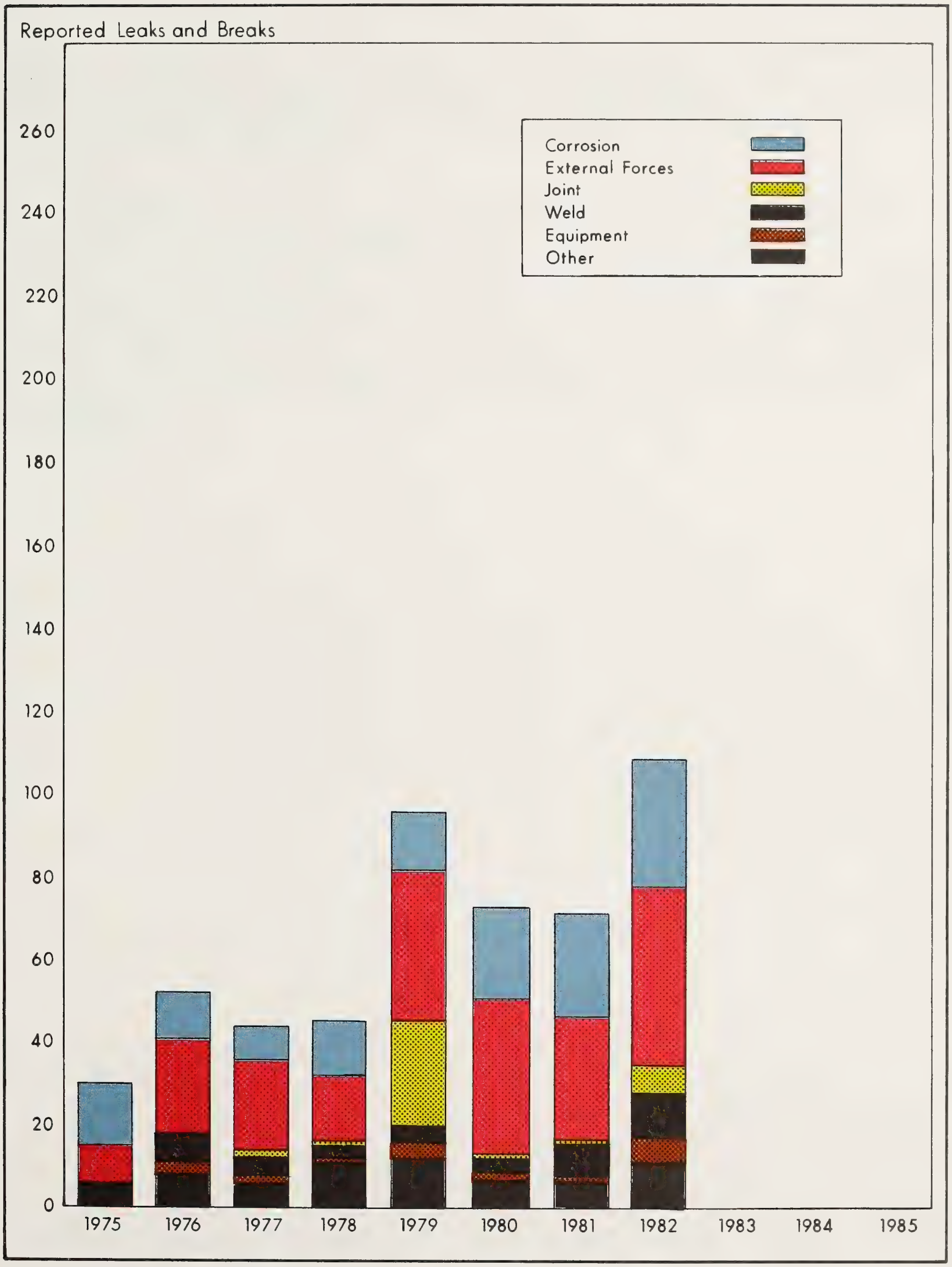

FIGURE 9 ANNUAL PIPELINE LEAKS AND BREAKS. Natural Gas

3.6.1 Performance of Sour Gas Pipelines

Hydrogen sulphide gas affects the performance of gas pipelines for sour service. Leaks of sour gas lines are viewed separately from sweet gas lines because of the aggressive behaviour to pipe materials. Internal corrosion occurs frequently in sour gas lines and accounts for the majority of leaks (Figure 5).

The distribution of sour gas leaks is shown in Figure 10 for the years 1975-1982. The number of incidents is low compared to other types of pipelines. Material and operation leaks occur randomly and leak trends cannot be established. This may be attributed to higher design standards and operation practices required for sour gas pipelines. Corrosion is the most significant aspect of sour gas pipeline performance. Although the leak rate is low, sour gas remains a major concern due to the nature of product transmitted and operators review pipeline performance with close regard.

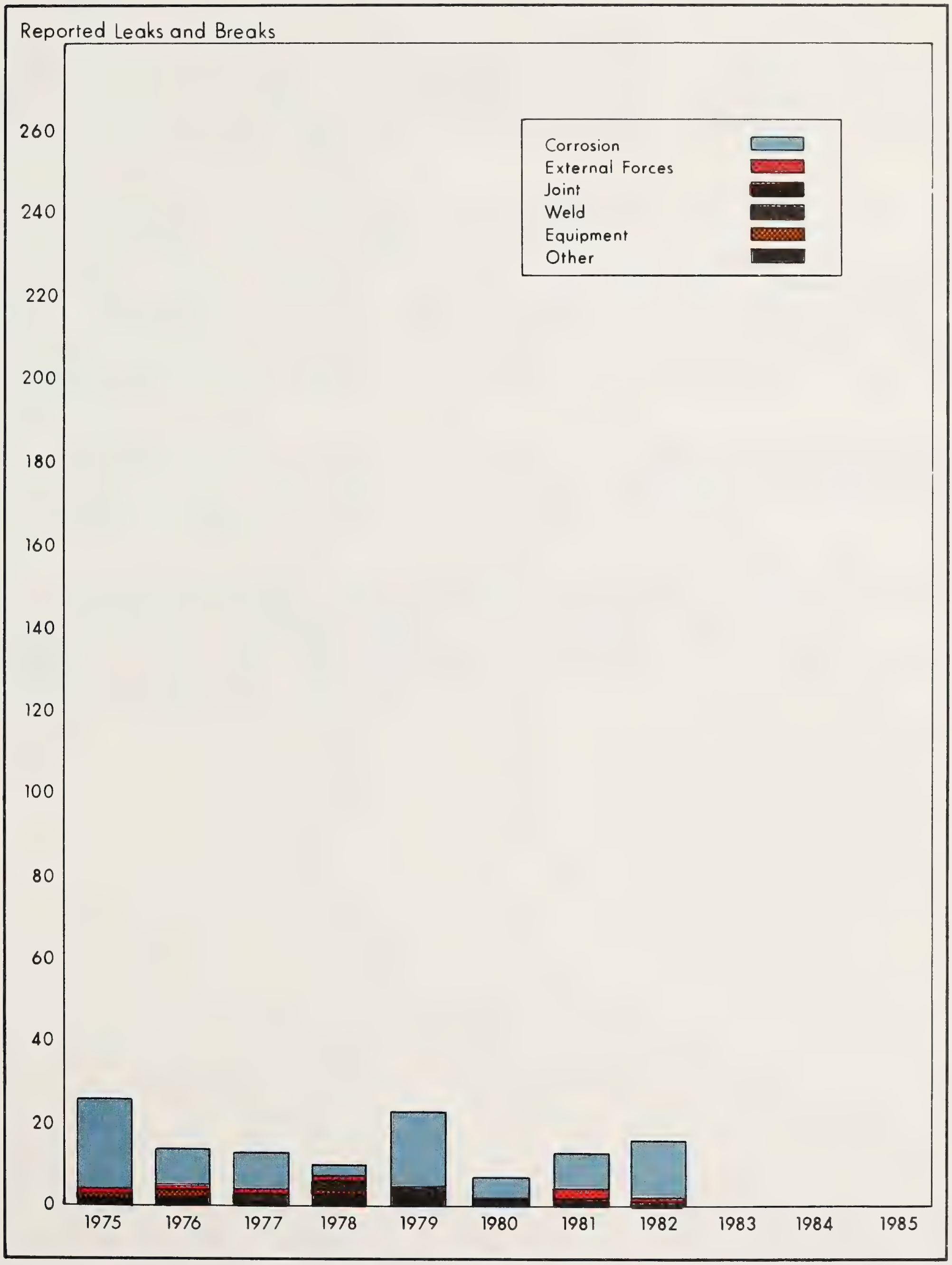

FIGURE 10 ANNUAL PIPELINE LEAKS AND BREAKS. Sour Gas

4 SUMMARY

The performance of pipelines used in the oil and gas industry has been reviewed with the use of leak and break statistics. Essentially it has been shown that each type of pipeline has individual leading leak causes. Each cause may not be independent and when reviewed, an overall problem in a pipeline type may appear.

Statistics are not intended to give exact solutions. By indicating the areas of greatest fault or least concern on each type of pipeline, statistics direct the investigation of operation performance. There is a limit to the detail provided by pipeline leak statistics. A much larger and more complex data base is required to evaluate leaks influenced by a number of variables. However, the analysis of individual leaks of pipelines can lead to engineering decisions and recommendations concerning pipeline design, construction, or operation.

Detailed leak analysis is not required when reviewing overall performance. The statistics have shown trends which have not significantly changed over the 8-year period. Major leak causes have not decreased in frequency of occurrence and remain areas of concern in daily operations.

The investigation of pipeline performance must involve an assessment of the frequency of pipeline leaks and breaks. Although the data is general in nature, specific areas to be reviewed are apparent in statistical summaries. When addressing the effective and economic operation of pipelines, the areas of greatest fault must be reduced in each type of pipeline service.

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